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ABSTRACT

The intelligibility of crosslanguage voice communication in American English was studied in situations where the phonemes of that language are uttered by American speakers and identified by speakers of German, French, and Mexican Spanish and in situations where they are uttered by speakers of German, French, and Mexican Spanish and identified by Americans. Nonsense syllable consonants were used as test items. Test items were in English, since international air-traffic communications, the principal area of focus, are carried out mostly in English. The consonants occur in initial and terminal positions in monosyllabic items and intervocally in disyllabic items. Each consonant-times-position was repeated in front-, central-, and back-vowel contexts to determine if vowels differentially affect the perception of the consonants. All the phonetic conditions were repeated in each of three transmission conditions: restricted bandwidth, white noise background, and babbling voice background. Findings indicate that in terms of the classes of phonemes, the stops in final position were by far the most difficult phonemes to identify for all listeners. The stimuli most difficult to perceive were in the noise and babbling conditions in the terminal position. Consonants in intervocalic position were more readily identified than in the other two positions. Recommendations for the improvement of international voice communications are offered. (SW)

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FINAL TECHNICAL REPORT

THE CROSSLANGUAGE INTELLIGIBILITY OF PHONEMES, SOURCES OF INTERFERENCE IN INTERNATIONAL VOICE COMMUNICATION

NATIONAL SCIENCE FOUNDATION STUDENT-ORIENTED PROGRAM
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1.0 INTRODUCTION

1.1 THE PROBLEM

The efficiency of crosslanguage voice communication is affected on the one hand by phonetic factors and on the other by the acoustic characteristics of the transmission medium used. This becomes vital in situations such as air-traffic control, where pilots of foreign arriving or departing aircraft are receiving directives and exchanging information with American ground personnel, and where American pilots are in voice communication with foreign airports. Human lives and the efficiency of operations are both involved. Improvement of such communications can be made on the human factors side by revising the procedural jargon in such a way as to minimize or avoid areas of phonetic difficulty and on the technical side by reducing or eliminating transmission factors that interfere with intelligibility. The phonetic factors involve (1) the pronunciation of the phonemes of one language by speakers of another and (2) the identification of the phonemes of one language by listeners whose native language is another. The transmission factors are obviously numerous, but the most important ones are assumed to be (1) bandwidth, (2) noise background and (3) irrelevant speech background.

1.2 SPECIFIC AIMS OF PRESENT STUDY

This study limits itself to the purely phonetic aspects of the question, in three arbitrarily chosen transmission conditions (restricted bandwidth, white noise background, babbling voice background). Lexical and grammatical context is eliminated from consideration here by the use of nonsense test items. The study is further limited to crosslanguage voice communication in American English in situations where the phonemes of that language are uttered by Amer-

ican speakers and identified by speakers of German, French and Mexican Spanish and where they are uttered by speakers of German, French and Mexican Spanish and identified by Americans. These limits are predicated on the fact that English is used in air-traffic control in the majority of the world's international airports. Finally, the study is limited to consonants, first to keep the research within feasible proportions, and second, since the functional load of vowel differentiation is relatively small in that language, given the neutralization of unaccented vowels. Accented vowels obviously contribute significantly to meaning and should accordingly be examined systematically in future studies.

1.3 METHODS USED IN PRESENT STUDY

The study consists of the analysis of the judgments made by groups of phonetically naive listeners of the four nationalities in question, as they attempt to identify American English consonants in nonsense syllables, recorded by speakers of languages that are not their own. The consonants occur in initial and terminal positions in monosyllabic items and intervocally in disyllabic items. Each consonant-times-position is repeated in front-, central- and back-vowel contexts to determine if vowels differentially affect the perception of the consonants. Finally, all the phonetic conditions noted above are repeated in each of three transmission conditions, as follows: The first is free of extraneous background but restricted to a bandwidth of approximately 300 to 3000 Hz. This condition remains common to the other two. The second adds a background of white noise, and the third a background of a number of voices talking simultaneously in several languages. The judgments made by the various groups of listeners are tabulated and analyzed statistically, and from these numerical results, analyses of the areas of interference are made and

appropriate conclusions and recommendations drawn.

2.0 DESCRIPTION OF TEST STIMULI

2.1 GENERAL

2.1.1 PHONETIC COMPOSITION OF STIMULI

Each of the four languages involved in this study has its own inventory of phonemes, and each of the foreign languages lacks some that exist in English and includes some that do not. Since international air-traffic communications, our principal area of focus, are carried out mostly in English, the phonemes to be tested were limited to those that occur in that language. As stated earlier, this study concerns situations where the speaker or the listener is always an American and the other a Frenchman, a German or a Mexican. British English is quite another problem and would merit a separate study. The list of consonants to be tested, represented by symbols of the International Phonetic Alphabet, is as follows:

a) Stops - p, t, k, b, d, g, ŋ

b) Fricatives - f, ʃ, θ, ð, v, z, h

c) Affricates - ʧ, ʤ

d) Liquids - r, l

e) Semi-consonant - w

A few consonants (m, n, s, ʒ, j) were excluded due to their identical characteristics in the languages in question or because of their almost negligible functional load. Besides, /ŋ/ was tested only in medial and terminal positions, and /h/ and /w/ only in initial and medial positions, both limitations corresponding to the distribution rules for those consonants in English. Except for the omissions noted above, each consonant was incorporated into a number of

logatomes (nonsense syllables) as follows: (1) initially, e.g., /pa/, (2) intervocalically, e.g., /apa/ and (3) in terminal position, e.g., /ap/. The three positions were repeated so as to include front, central and back vowels, i.e., /i/, /a/ and /u/. The purpose here was not to test the intelligibility of the vowels but to determine in a general way how, if at all, vowels affect the identification of consonants with which they are contiguous. It is known, for example, that in English at least there is a tendency to confuse labial and velar stops (/p/ and /k/, /b/ and /g/) when these are paired with back vowels.

2.1.2 ENUNCIATION OF TEST STIMULI

A native speaker of a standard dialect of each of the four languages in question recorded the stimuli. They are furthermore all language specialists and are thus phonetically very knowledgeable. They uttered the items in an American English linguistic frame of reference, that is to say, as if they were words of English, but generally in the phonetic frame of reference of their native tongues, in other words, with their native buccal posture and dynamic habits of articulation. A degree of influence from the spelling of the items was assumed, corresponding to generally observed habits of people of the nationalities involved of the social background and degree of education that become pilots or air-traffic personnel. A detailed description of their pronunciation of the test items will be given in the following sections.

2.2 AMERICAN ACCENT STIMULI

This language of course presents no difficulties. The speaker's accent represents the educated middle-class of the Middle Atlantic States, a dialect that has often been designated as "General American". The stops all had normal

degrees of aspiration and affrication, except in terminal position where they were un-released. The /r/ was of the standard retroflex variety, and the /l/ was "dark".

2.3 GERMAN ACCENT STIMULI

The stimuli for the version with a German accent were recorded by an educated, middle-class speaker of standard High German. Because of the characteristics of the German phonetic system, the following phonemes basically retained their German pronunciation: The voiced stops, b, d, g, were devoiced in terminal position, the /v/ was devoiced in terminal and initial positions, the English retroflex-/r/ was pronounced as a centro-pharyngeal fricative in all positions, and the English latero-alveolar "dark" -/l/ became latero-dental in all positions. English phonemes that do not exist in German were pronounced with their closest German substitutes. Thus, in all positions, /w/ was recorded as /v/ and /θ/ as /s/. In initial and medial positions, voiced-th became /z/, and in terminal position it became /s/.

2.4 FRENCH ACCENT STIMULI

The speaker's accent represents the educated middle-class of the Paris Basin, the dialect generally regarded as Standard French. All stimuli were recorded with the same degree of stress, and in VCV logatomes both syllables were equally stressed. Four consonants of English do not exist in French: (1) The palato-velar nasal stop, /ŋ/, exists in French only in a limited number of words borrowed from English, e.g., un parking. It was recorded with a slight anticipation during the preceding vowel in stimuli where the consonant was in medial or terminal position. Thus, /aŋa/ was thus recorded as [ãŋa]. (2) The glottal fricative, /h/, was pronounced as in English since it does not present any articulatory problem for the French. (3, 4) The unvoiced dental fricative,

/θ/, and its voiced cognate, /ð/, constitute the main difficulty for French speakers, since they have no equivalents in the phonetic framework of their language. The following approximations were substituted: /θ/ was pronounced as /s/ with a lisp and /ð/ as a /z/ with a lisp, and both were more alveolar than dento-alveolar. In addition, the retroflex -/r/ was replaced by the standard French pharyngeal fricative "r-grasseyé", and "clear" /l/ was used in place of the "dark" version of American English.

2.5 MEXICAN ACCENT STIMULI

Strictly speaking, of the 19 English consonants selected for testing, /f/, /w/ and /ʧ/ are the only phonemes common to both English and Mexican Spanish. The phoneme /f/ was used in spite of its universality in order to compare its perception with that of /θ/; /ʧ/ was likewise of interest to Spanish in comparison to /ʃ/, a phoneme that does not exist in Spanish, besides being of special interest to French and German; and /w/ was used because of its interest to German. The remaining 16 American English phonemes present special problems to native speakers of Spanish. The speaker's accent characterizes that of a member of the educated middle-class of Mexico who has some knowledge of English but who exhibits a strong accent when he speaks it. Accordingly, the voiced plosives, p, t, k, were unaspirated in initial and intervocalic positions, and in final position rendered with a barely audible release characteristic of native speakers of Spanish unaccustomed to final stops. The voiced plosives, b, d, g, were rendered with less aspiration in initial position than is the custom in English, and in intervocalic and final positions they were rendered as voiced fricatives. The affricate, /ʧ/, was rendered as in English in all positions, and /ʤ/ was rendered as /ŷ/ (palato-alveolar fricative) in initial and intervocalic positions. The unvoiced fricative, /f/, was rendered as in English

in all positions, /θ/ as an affricated dental (/tθ/) in all positions, /ʃ/ as /ʧ/ in initial and intervocalic positions and as /ʃ/ in final position. American English /h/ became a velar (/x/) in the two positions where it occurs in that language, i.e., initial and intervocalic. The voiced fricative, /v/, was rendered as /b/ in initial position since no voiced labial dental exists in Spanish and as bilabial fricative in intervocalic position and in final position. Interdental /ð/ was rendered as /d/ in initial and final positions and as /ð/ in intervocalic position. Voiced /z/ was rendered as /s/ in all positions. American English /l/, which is alveolar, became dental in all positions, and the palatal retroflex /r/ became alveolar with a slight trill in all positions. The glide /w/ was rendered as in English in the two positions tested, i.e., initial and intervocalic.

3.0 PREPARATION OF TESTS

3.1 ITEMS RECORDED / SELECTION OF SAMPLES

The native speakers of each of the four languages in question recorded each stimulus four times in succession. The individual samples were then monitored and appraised, and an appropriate selection was made on the basis of the speaker's naturalness and voice quality and the evenness of vocal stress, volume and pitch.

3.2 ORGANIZATION OF TESTS

Five test stimuli from each of the four language recordings were selected as training items for the purpose of being administered prior to each testing session. These differed somewhat from one language to another because of their different areas of difficulty. The actual test stimuli, 162 in number, were cut from the master tape and spliced into a new tape according to a quasi-

random table. The stimuli were divided into eighteen groups, each containing nine stimuli. Each stimulus was separated from the next within the same group by six seconds of blank tape, with ten seconds of silence left between groups. The entire sequence was then repeated but in reverse order from the first. The two presentations were conceived as a means of cancelling out or at least minimizing fatigue effects.

3.3 TECHNICAL DETAILS

3.3.1 RECORDING CONDITIONS

Recordings were made on an Ampex 1/2-track monaural professional tape deck, with an Electro-Voice cartoid dynamic microphone. The microphone was placed at an equal distance from all the speakers during the recording sessions in order to avoid inconsistent tonal variations due to bass doubling. The studio is an acoustically treated rectangular room 98' x 15' x 18') with a reverberation time of approximately .5 seconds.

3.3.2 ACOUSTIC BACKGROUNDS

These were added to heighten differences in phonetic identifiability among the various test items in adverse transmission conditions of the types likely to occur in situations such as air-traffic control communications. Three acoustic backgrounds were used in the tests. The first, common to all three conditions, shall be referred to as "restricted bandwidth". This was set at approximately 300 - 3000 Hz, through maximum attenuation of frequencies beyond that range with a PULTEC graphic equalizer. The second condition, a white noise background, was mixed, with a signal-to-noise ratio of approximately 10 between the speaker's voice and the noise. The latter was derived from a normal FM radio, tuned between stations. No equalization of that signal was required.

The third condition utilized a background of babbling voices and similarly maintains a signal-to-noise ratio between the speaker's voice and the babbling of approximately 10. Five speakers for the babbling read texts in their native languages (German, French, English and Spanish) with no dominant stresses or intonations occurring. During the mixdown, maximum compression was used on the five background voices.

4.0 ADMINISTRATION OF TESTS

4.1 SELECTION OF LISTENERS

A total of 60 subjects were recruited as listeners in the project. Of these, 30 are Americans, 10 are French, 10 are native speakers of Mexican Spanish and 10 are German. Criteria for selection were age (18 to 50 yrs.) and normal hearing. Each subject was to listen to the tape-recorded language to which he or she had no previous exposure, and each was required to attend two 1/2-hour testing sessions, with a one day interval between the two.

4.2 CONDITIONS AND ORDERS PRESENTED IN EACH SESSION

In order to eliminate possible effects of fatigue and/or memory, the two test orders (forward and reverse) were rotated during each session as follows:

TEST SESSION - A:

	Conditions	Test order
(1)	Restricted Bandwidth	Forward Random
(2)	White Noise Background	Reversed Random
(3)	Babbling Voice Background	Normal Random

TEST SESSION - B:

(1)	Restricted Bandwidth	Reversed Random
(2)	White Noise Background	Normal Random
(3)	Babbling Voice Background	Reversed Random

4.3 DIRECTIONS GIVEN TO THE SUBJECTS

Directions to the subjects were taped in English and played on a tape recorder other than the one used to present the stimuli. Typed copies of these instructions were placed before the subjects so that they could read as well as listen to them. They were instructed to listen carefully to the test syllables, and then to spell them as they were accustomed to doing in their native language. Their judgments were to be written on special sheets provided for the tests. Also included in the instructions were special spelling notations differing somewhat from one language to another. In order to aid the researchers, when the answers were later analysed, all the listeners were instructed to indicate the difference between voiced and voiceless "th" by writing a "1" after the "th" if they heard /θ/ and a "2" if they heard /ð/. American, French and German subjects were further instructed to write "ng" for /ŋ/. American subjects alone were instructed to write "j" for /dʒ/ and "g" for /g/. Spanish speaking subjects were instructed to write the letter "v" for /v/, "sh" for /ʃ/ and "j" for /dʒ/. German subjects were instructed to write "w" for both /v/ and /w/, since the letter "v" does not exist in the German alphabet. The differentiation between the two was to be made by adding a "1" for /v/ and a "2" for /w/.

5.0 PRESENTATION OF NUMERICAL RESULTS

5.1 AMERICAN ACCENT / FRENCH LISTENERS

The figures in the tables in this section represent percentages of correct identifications.

5.1.1 AMERICAN ACCENT / FRENCH LISTENERS (INITIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	98	80	72	98	92	73	100	68	48
/p/	95	80	80	100	75	65	100	85	35
/t/	95	100	75	100	90	30	100	100	45
/k/	100	65	25	100	95	75	100	10	5
/b/	100	100	90	100	100	75	100	95	90
/d/	100	65	65	95	100	95	100	80	60
/g/	100	70	100	95	90	100	100	40	50
Nasal: /ŋ/	No stimuli in this position								
Affricates:	75	95	78	100	98	80	92	80	60
/ʧ/	60	90	80	100	95	65	85	60	20
/ʤ/	100	100	75	100	100	95	100	100	100
Fricatives:	76	54	58	63	69	58	82	74	57
/f/	95	55	65	75	80	90	85	65	75
/θ/	35	20	15	25	50	30	70	55	35
/ʃ/	100	95	75	100	100	100	100	90	100
/h/	90	35	30	85	85	60	85	85	0
/v/	60	50	65	30	20	5	85	70	55
/ð/	60	55	65	70	70	60	70	70	65
/z/	90	70	90	55	80	60	80	85	70
Liquids:	98	90	85	100	98	68	92	85	80
/r/	95	80	80	100	100	80	90	80	75
/l/	100	100	90	100	95	55	95	90	85
Semi-cons:	100	100	90	90	80	70	90	30	45
/w/	100	100	90	90	80	70	90	30	45

5.1.2 AMERICAN ACCENT / FRENCH LISTENERS (MEDIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	100	92	73	97	93	91	99	85	72
/p/	100	75	80	100	100	85	100	80	70
/t/	100	100	85	85	80	90	100	90	100
/k/	100	90	75	100	95	90	100	90	55
/b/	100	100	100	100	100	100	100	100	75
/d/	100	90	60	95	85	85	95	100	75
/g/	100	100	40	100	100	95	100	50	60
Nasal:	20	25	20	20	20	20	5	0	5
/ŋ/	20	25	20	20	20	20	5	0	5
Affricates:	100	95	92	100	100	100	100	100	98
/ʧ/	100	90	90	100	100	100	100	100	100
/ʤ/	100	100	95	100	100	100	100	100	95
Fricatives:	84	71	71	70	68	71	85	74	67
/f/	95	90	90	90	95	80	100	90	85
/θ/	75	70	55	20	25	25	75	45	30
/ʃ/	100	100	100	100	100	100	100	100	100
/h/	85	85	70	85	95	90	90	65	70
/v/	80	20	60	70	30	55	85	75	85
/ð/	60	50	40	35	65	50	55	65	15
/z/	90	80	809	85	65	95	90	80	85
Liquids:	100	95	98	85	80	75	98	83	78
/r/	100	90	95	100	90	100	95	80	80
/l/	100	100	100	70	70	50	100	85	75
Semi-cons:	95	85	95	100	95	100	85	70	75
/w/	95	85	95	100	95	100	85	70	75

5.1.3 AMERICAN ACCENT / FRENCH LISTENERS (TERMINAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	28	13	17	55	48	33	18	9	13
/p/	10	5	20	20	35	10	40	20	15
/t/	15	15	15	15	15	40	5	0	15
/k/	25	10	5	85	70	50	25	5	15
/b/	10	0	0	65	20	5	10	0	25
/d/	45	25	55	45	45	25	20	10	10
/g/	65	25	5	100	100	70	5	20	5
Nasal:	55	65	25	80	65	80	15	10	5
/ŋ/	55	65	25	80	65	80	15	10	5
Affricates:	98	98	80	95	75	58	98	92	68
/ʧ/	95	100	70	90	100	95	95	100	95
/ʤ/	100	95	90	100	50	20	100	85	40
Fricatives:	78	57	52	71	52	48	69	80	52
/f/	90	75	80	100	85	90	100	90	90
/θ/	55	15	10	25	5	5	20	20	5
/ʃ/	100	95	100	100	100	75	100	85	70
/h/	No stimuli in this position								
/v/	80	50	30	90	80	75	80	65	60
/ð/	50	20	10	10	25	10	25	20	10
/z/	95	85	85	100	70	35	90	80	65
Liquids:	68	55	48	48	20	30	50	40	42
/r/	90	90	85	90	25	55	90	80	85
/l/	45	20	10	5	15	5	10	0	0
Semi-cons:									
/w/	No stimuli in this position								

5.2.1 AMERICAN ACCENT / GERMAN LISTENERS (INITIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	99	80	70	97	82	81	98	61	51
/p/	100	80	80	100	50	65	95	40	25
/t/	100	95	45	100	100	75	100	100	90
/k/	100	60	30	100	75	60	95	30	15
/b/	100	100	85	100	100	95	95	95	80
/d/	100	85	95	95	100	95	100	75	50
/g/	95	65	85	85	70	95	100	30	45
Nasal: /ŋ/	No stimuli in this position								
Affricates:	78	85	72	87	90	75	72	60	50
/ʧ/	70	90	60	100	95	70	65	40	15
/ʤ/	85	80	85	75	85	80	80	80	85
Fricatives:	70	49	53	62	64	51	69	60	59
/f/	80	40	35	90	70	70	95	55	80
/θ/	25	5	15	5	10	10	20	35	10
/ʃ/	100	70	85	100	100	90	100	80	100
/h/	100	40	85	100	100	65	100	65	55
/v/	80	65	55	55	50	20	65	75	65
/ð/	20	25	5	25	35	40	10	20	5
/z/	90	95	85	65	85	60	90	90	95
Liquids:	100	80	82	100	90	82	100	88	88
/r/	100	65	65	100	80	90	100	90	85
/l/	100	95	100	100	100	75	100	85	90
Semi-cons:	75	80	80	95	60	45	65	45	45
/w/	75	80	80	95	60	45	65	45	45

5.2.2 AMERICAN ACCENT / GERMAN LISTENERS (MEDIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	97	91	70	100	88	86	98	82	76
/p/	95	90	70	100	100	95	100	90	80
/t/	100	95	90	100	95	95	100	100	100
/k/	95	80	80	100	90	35	90	60	75
/b/	90	95	85	100	95	100	100	100	90
/d/	100	90	65	100	70	90	95	90	75
/g/	100	95	30	100	80	100	100	50	35
Nasal:	60	35	40	85	85	65	25	0	0
/ŋ/	60	35	40	85	85	65	25	0	0
Affricates:	92	92	88	90	90	85	90	90	75
/ʧ/	100	95	85	95	90	85	95	90	75
/ʤ/	85	90	90	85	90	85	85	90	75
Fricatives:	76	64	64	67	63	63	73	53	59
/f/	70	65	60	100	75	90	90	80	90
/θ/	50	25	10	5	5	5	35	5	5
/ʃ/	100	100	100	100	100	100	100	100	95
/h/	100	100	95	100	100	100	100	30	50
/v/	80	45	75	70	60	40	75	55	70
/ð/	35	25	15	5	20	10	10	0	5
/z/	95	90	95	90	80	95	100	100	95
Liquids:	100	95	100	85	85	82	100	88	90
/r/	100	90	100	100	95	100	100	90	100
/l/	100	100	100	70	75	65	100	90	100
Semi-cons:	75	80	45	85	80	70	40	25	70
/w/	75	80	45	85	80	70	40	25	70

5.2.3 AMERICAN ACCENT / GERMAN LISTENERS (TERMINAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	29	12	10	46	32	18	19	10	4
/p/	5	0	5	15	5	0	35	30	15
/t/	0	10	5	10	20	10	0	0	0
/k/	0	5	0	50	35	5	15	25	0
/b/	5	5	0	70	30	15	10	5	5
/d/	75	50	45	30	30	25	40	0	5
/g/	90	0	5	100	70	55	15	0	0
Nasal:	30	35	15	75	65	90	15	5	0
/ŋ/	30	35	15	75	65	90	15	5	0
Affricates:	88	85	65	82	62	30	90	60	55
/ʧ/	95	85	75	90	80	55	90	85	80
/ʤ/	80	85	55	75	45	5	90	35	30
Fricatives:	65	45	34	55	46	38	65	53	40
/f/	55	60	45	90	85	90	90	80	75
/θ/	40	20	5	0	5	0	0	5	0
/ʃ/	100	100	100	100	95	85	100	90	90
/h/	No stimuli in this position								
/v/	75	10	0	35	40	20	70	50	35
/ð/	20	0	0	10	0	0	35	0	0
/z/	100	80	55	100	50	30	95	95	40
Liquids:	90	52	68	65	38	68	57	45	52
/r/	100	75	100	100	40	65	100	90	95
/l/	80	30	35	30	35	70	15	0	10
Semi-cons:									
/w/	No stimuli in this position								

5.3.1 AMERICAN ACCENT / MEXICAN LISTENERS (INITIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	97	77	63	78	68	67	95	53	47
/p/	100	80	80	90	45	35	100	40	20
/t/	100	100	45	70	85	50	100	100	55
/k/	90	70	25	100	75	75	100	15	25
/b/	95	100	75	70	70	70	85	80	85
/d/	100	60	75	70	85	75	95	70	45
/g/	95	50	80	65	45	95	90	15	50
Nasal: /ŋ/	No stimuli in this position								
Affricates:	62	62	72	82	72	58	88	52	38
/ʧ/	40	55	70	90	75	45	55	35	5
/ʤ/	85	70	75	75	70	70	70	70	70
Fricatives:	66	49	39	69	56	49	70	53	49
/f/	90	45	25	90	55	75	100	70	75
/θ/	0	0	0	30	10	10	15	5	0
/ʃ/	70	65	50	75	60	60	75	60	55
/h/	100	45	55	100	95	75	90	50	55
/v/	70	70	50	45	40	15	90	70	60
/ð/	45	20	0	60	35	25	20	25	10
/z/	85	100	95	85	100	85	100	90	85
Liquids:	90	95	82	95	98	90	85	98	92
/r/	85	90	65	90	95	90	75	95	90
/l/	95	100	100	100	100	90	95	100	95
Semi-cons:	100	95	90	100	85	40	75	35	75
/w/	100	95	90	100	85	40	75	35	75

5.3.2 AMERICAN ACCENT / MEXICAN LISTENERS (MEDIAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	98	82	59	92	88	76	91	75	72
/p/	100	85	65	100	100	90	100	70	35
/t/	100	95	75	95	100	95	95	90	100
/k/	100	70	75	95	95	25	90	70	60
/b/	95	70	50	75	70	70	85	85	55
/d/	95	100	55	90	80	85	80	95	60
/g/	100	75	35	100	85	90	95	35	70
Nasal:	5	10	15	10	20	25	25	0	0
/ŋ/	5	10	15	10	20	25	25	0	0
Affricates:	82	75	82	78	78	80	68	78	80
/ʧ/	90	70	85	75	80	90	65	75	75
/ʤ/	75	80	80	80	75	70	70	80	85
Fricatives:	69	55	58	66	61	60	66	46	45
/f/	95	70	80	100	85	80	90	80	85
/θ/	30	5	10	15	10	5	20	5	5
/ʃ/	70	60	65	75	55	60	75	60	60
/h/	95	95	100	100	100	100	90	40	30
/v/	65	35	65	75	60	50	75	45	60
/ð/	45	35	10	20	35	50	35	15	20
/z/	85	85	75	80	85	75	80	80	55
Liquids:	90	95	95	82	98	80	95	78	70
/r/	90	90	90	95	100	85	90	75	80
/l/	90	100	100	70	95	75	100	80	60
Semi-cons:	100	95	100	100	90	95	45	60	70
/w/	100	95	100	100	90	95	45	60	70

5.3.3 AMERICAN ACCENT / MEXICAN LISTENERS (TERMINAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	38	21	9	52	43	28	24	17	8
/p/	35	25	10	40	20	10	55	30	20
/t/	30	15	25	45	25	45	20	10	5
/k/	5	0	0	50	50	20	10	10	0
/b/	15	15	0	40	35	5	40	30	20
/d/	75	50	15	40	40	25	5	0	0
/g/	65	20	5	100	90	65	15	20	0
Nasal:	90	20	15	45	50	55	5	0	0
/ŋ/	90	20	15	45	50	55	5	0	0
Affricates:	78	80	68	80	65	50	82	60	58
/ʧ/	95	95	95	90	85	80	90	90	80
/ʤ/	60	65	40	65	45	20	75	30	35
Fricatives:	63	42	34	47	47	32	52	39	28
/f/	85	75	60	95	80	75	85	80	60
/θ/	25	5	0	5	5	0	0	0	0
/ʃ/	65	50	60	70	65	45	70	50	40
/h/	No stimuli in this position								
/v/	65	25	20	50	55	40	65	40	45
/ð/	65	50	10	0	25	20	15	15	10
/z/	75	50	55	60	50	15	70	50	15
Liquids:	82	48	55	72	28	60	52	18	22
/r/	100	55	70	95	25	75	100	35	40
/l/	65	40	40	50	40	45	5	0	5
Semi-cons:									
/w/	No stimuli in this position								

5.4.1 FRENCH ACCENT / AMERICAN LISTENERS (INITIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	93	65	76	74	50	68	93	66	84
/p/	80	15	20	55	30	25	70	30	70
/t/	95	85	100	25	20	20	100	85	90
/k/	100	45	65	90	25	75	100	80	85
/b/	85	95	100	85	80	100	90	100	90
/d/	100	100	100	90	85	90	100	65	100
/g/	100	50	70	100	60	95	100	35	70
Nasal: /ŋ/	No stimuli in this position								
Affricates:	80	72	82	98	98	95	80	72	80
/ʧ/	90	90	95	95	100	100	90	95	95
/ʤ/	70	55	70	100	95	90	70	35	65
Fricatives:	64	62	66	56	46	51	71	55	61
/f/	80	90	85	95	70	90	100	95	100
/θ/	0	0	0	5	0	0	0	0	0
/ʃ/	95	95	100	90	80	90	100	80	95
/h/	100	80	85	100	50	75	100	35	40
/v/	75	70	95	5	20	0	100	75	90
/ð/	0	0	0	0	0	0	0	0	0
/z/	100	100	100	100	100	100	100	100	100
Liquids:	85	80	88	60	62	70	75	68	80
/r/	70	60	75	20	25	40	50	65	60
/l/	100	100	100	100	100	100	100	70	100
Semi-cons:	100	80	95	95	100	100	85	60	50
/w/	100	80	95	95	100	100	85	60	50

5.4.2 FRENCH ACCENT / AMERICAN LISTENERS (MEDIAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	98	79	82	96	89	93	99	82	92
/p/	100	95	85	100	100	90	100	90	55
/t/	100	100	100	100	90	100	95	80	100
/k/	90	35	30	85	55	70	100	65	100
/b/	100	90	95	100	100	100	100	80	100
/d/	100	65	85	90	95	100	100	100	100
/g/	95	90	95	100	95	100	100	80	95
Nasal:	95	65	95	95	95	100	90	15	85
/ŋ/	95	65	95	95	95	100	90	15	85
Affricates:	80	78	82	90	95	92	88	92	85
/ʧ/	95	90	95	95	95	100	95	100	95
/ʤ/	65	65	70	85	95	85	80	85	75
Fricatives:	70	58	64	64	53	61	69	49	56
/f/	100	65	100	80	45	80	100	85	100
/θ/	0	0	0	15	5	5	0	0	0
/ʃ/	90	90	90	90	80	85	85	85	80
/h/	100	50	60	95	95	100	100	5	15
/v/	100	100	100	80	50	70	100	65	100
/ð/	0	0	0	0	0	0	0	0	0
/z/	95	100	100	90	95	90	100	100	100
Liquids:	100	95	98	53	53	55	78	45	72
/r/	100	90	100	5	5	10	55	55	50
/l/	100	100	95	100	100	100	100	35	95
Semi-cons:	100	85	100	95	80	95	70	55	50
/w/	100	85	100	95	80	95	70	55	50

5.4.3 FRENCH ACCENT / AMERICAN LISTENERS (TERMINAL POSITION)

Vowel:	/i/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	91	44	47	90	64	67	82	38	58
/p/	85	20	15	85	70	50	45	5	25
/t/	95	60	55	95	85	100	70	15	70
/k/	75	20	5	75	50	35	80	55	65
/b/	100	70	85	100	65	85	100	55	40
/d/	95	35	50	90	30	35	95	30	60
/g/	95	60	70	100	85	95	100	70	90
Nasal:	100	70	95	95	95	100	100	65	55
/ŋ/	100	70	95	95	95	100	100	65	55
Affricates:	80	80	82	72	85	78	72	58	82
/ʧ/	90	100	90	75	90	75	80	75	95
/ʤ/	70	60	75	70	80	80	65	40	70
Fricatives:	57	46	54	56	42	50	62	52	53
/f/	100	65	85	95	60	70	100	85	85
/θ/	0	0	0	0	0	0	0	0	0
/ʃ/	90	80	85	85	80	85	85	75	80
/h/	No stimuli in this position								
/v/	70	50	70	65	40	65	90	55	70
/ð/	0	0	0	0	0	0	0	0	0
/z/	80	80	85	90	70	85	100	95	85
Liquids:	78	70	65	55	45	30	57	62	50
/r/	65	95	80	10	5	5	15	25	20
/l/	90	45	50	100	85	55	100	100	80
Semi-cons:									
/w/	No stimuli in this position								

5.5.1 GERMAN ACCENT / AMERICAN LISTENERS (INITIAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	99	58	75	96	81	84	93	49	79
/p/	95	30	55	100	75	80	95	50	90
/t/	100	90	100	90	100	100	100	95	100
/k/	100	100	85	100	90	70	95	35	95
/b/	100	15	65	85	45	70	70	0	5
/d/	100	30	70	100	90	95	100	95	100
/g/	100	85	75	100	85	90	100	20	85
Nasal: /ŋ/	No stimuli in this position								
Affricates:	95	90	92	92	65	78	50	40	25
/ʧ/	100	95	100	95	50	85	100	65	40
/ʤ/	90	85	85	90	80	70	0	15	10
Fricatives:	59	48	52	60	57	48	57	49	49
/f/	80	70	95	100	90	95	100	95	95
/θ/	0	0	0	0	45	0	0	0	0
/ʃ/	100	100	100	100	95	100	100	100	100
/h/	100	60	60	100	25	25	100	50	50
/v/	0	0	5	0	20	15	0	0	0
/ð/	35	5	10	20	20	5	0	0	0
/z/	100	100	100	100	100	100	100	95	95
Liquids:	72	38	32	65	42	52	52	32	20
/r/	100	65	45	100	85	100	95	65	35
/l/	45	10	20	30	0	5	10	0	5
Semi-cons:	0	0	10	0	0	0	0	0	0
/w/	0	0	10	0	0	0	0	0	0

5.5.2 GERMAN ACCENT / AMERICAN LISTENERS (MEDIAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	99	71	80	84	71	80	94	61	78
/p/	100	75	95	100	80	85	100	35	95
/t/	100	90	100	90	90	85	100	100	95
/k/	95	100	100	100	85	100	100	65	70
/b/	100	80	60	20	20	15	90	55	45
/d/	100	40	55	95	55	95	100	50	95
/g/	100	40	75	100	100	100	75	60	65
Nasal:	100	90	100	100	50	100	95	95	95
/ŋ/	100	90	100	100	50	100	95	95	95
Affricates:	50	55	50	95	78	92	82	85	70
/ʧ/	100	100	95	90	60	85	100	80	100
/ʤ/	0	10	5	100	95	100	65	90	40
Fricatives:	69	69	69	70	69	60	71	64	66
/f/	100	100	100	100	90	100	100	70	100
/θ/	0	0	0	0	0	0	0	0	0
/ʃ/	95	100	100	100	100	100	100	100	95
/h/	90	100	95	100	100	95	100	80	80
/v/	100	90	90	95	95	75	100	100	90
/ð/	0	0	0	0	0	0	0	0	0
/z/	95	95	95	95	100	100	100	100	100
Liquids:	98	75	78	58	75	60	65	68	68
/r/	95	75	55	100	90	95	80	90	90
/l/	100	75	100	15	60	25	50	45	45
Semi-cons:	0	0	0	0	0	0	0	0	0
/w/	0	0	0	0	0	0	0	0	0

5.5.3 GERMAN ACCENT / AMERICAN LISTENERS (TERMINAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	65	49	56	60	48	55	61	35	40
/p/	100	100	90	100	85	95	100	50	65
/t/	100	90	90	90	50	70	100	100	100
/k/	95	90	100	85	80	80	95	40	40
/b/	0	0	0	0	0	0	0	0	10
/d/	15	5	5	0	0	0	70	25	25
/g/	80	50	50	85	75	85	0	0	0
Nasal:	100	65	75	100	95	95	75	70	80
/ŋ/	100	65	75	100	95	95	75	70	80
Affricates:	90	85	95	98	95	88	62	50	58
/ʤ/	100	90	100	95	90	100	75	55	95
/ʧ/	80	75	90	100	100	75	50	45	20
Fricatives:	47	48	45	48	47	46	50	47	50
/f/	100	100	95	95	90	85	100	95	100
/θ/	0	0	0	0	0	0	0	0	0
/ʃ/	100	95	100	100	100	100	100	95	100
/h/	No stimuli in this position								
/v/	0	0	0	0	5	5	0	0	0
/ð/	0	0	0	0		0	0	0	0
/z/	80	90	75	90	85	85	100	95	100
Liquids:	58	55	55	55	38	45	67	45	60
/r/	85	50	75	100	70	85	55	10	40
/l/	30	60	35	10	5	5	80	80	80
Semi-cons: /w/	No stimuli in this position								

5.6.1 MEXICAN ACCENT / AMERICAN LISTENERS (INITIAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	41	39	37	54	39	41	57	41	30
/p/	5	0	10	20	20	15	15	0	0
/t/	20	50	10	20	10	5	15	15	0
/k/	30	0	20	40	20	25	15	15	15
/b/	90	75	80	80	80	55	100	90	95
/d/	100	15	0	75	55	75	100	70	5
/g/	0	95	100	90	50	70	95	55	65
Nasal: /ŋ/	No stimuli in this position								
Affricates:	78	45	85	98	50	50	100	15	75
/ʧ/	55	90	85	95	85	95	100	30	15
/ʤ/	100	0	85	100	15	5	100	0	0
Fricatives:	22	9	14	11	11	8	35	18	18
/f/	70	15	25	70	50	45	50	35	15
/θ/	35	5	25	30	20	10	75	25	35
/ʃ/	0	0	15	0	0	0	0	0	0
/h/	40	35	35	75	5	0	85	70	70
/v/	5	5	0	0	0	0	0	0	5
/ð/	5	0	0	0	5	0	0	0	0
/z/	0	0	0	0	0	0	0	0	0
Liquids:	90	58	52	95	90	92	92	72	80
/r/	85	60	50	95	90	95	95	85	90
/l/	95	55	55	95	90	90	90	60	70
Semi-cons:	20	20	10	70	70	80	75	25	20
/w/	20	20	10	70	70	80	75	25	20

5.6.2 MEXICAN ACCENT / AMERICAN LISTENERS (MEDIAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	63	53	51	60	61	57	59	51	53
/p/	95	75	95	70	65	40	75	45	80
/t/	100	95	90	70	85	90	100	90	85
/k/	100	95	90	90	90	100	100	95	95
/b/	5	0	0	25	35	15	5	15	15
/d/	5	25	5	5	5	0	35	55	40
/g/	75	30	25	100	85	95	40	5	5
Nasal:	45	15	40	75	5	0	85	35	20
/ŋ/	45	15	40	75	5	0	85	35	20
Affricates:	80	78	50	92	95	90	80	95	75
/ʧ/	100	90	100	100	100	90	65	90	70
/ʤ/	60	65	0	85	90	90	95	100	80
Fricatives:	48	27	27	32	26	33	36	31	37
/f/	100	90	60	100	70	75	90	80	85
/θ/	45	40	25	25	10	14	0	0	0
/ʃ/	0	0	0	0	0	5	0	0	0
/h/	80	0	50	75	40	60	90	80	85
/v/	80	45	35	5	35	35	45	40	55
/ð/	30	15	10	20	30	40	30	15	35
/z/	0	0	0	0	0	0	0	0	0
Liquids:	40	32	42	92	78	80	60	68	50
/r/	55	30	75	85	55	60	85	80	75
/l/	25	15	10	100	100	100	35	55	25
Semi-cons:	35	45	10	65	100	75	10	5	0
/w/	35	45	10	65	100	75	10	5	0

5.6.3 MEXICAN ACCENT / AMERICAN LISTENERS (TERMINAL POSITION)

Vowel:	/ɪ/			/a/			/u/		
Condition:	1	2	3	1	2	3	1	2	3
Stops:	40	50	16	39	38	33	34	15	8
/p/	75	0	20	90	70	65	45	30	20
/t/	70	20	45	75	85	75	95	45	30
/k/	0	20	0	20	50	25	0	10	0
/b/	0	75	0	0	5	5	0	0	0
/d/	10	90	25	10	5	5	20	5	0
/g/	85	95	5	40	10	25	45	0	0
Nasal:	10	10	20	0	5	5	20	5	15
/ŋ/	10	10	20	0	5	5	20	5	15
Affricates:	90	85	92	95	49	98	100	90	88
/ʧ/	100	90	100	100	95	100	100	100	95
/ʤ/	80	80	85	90	0	95	100	80	80
Fricatives:	48	14	39	52	46	38	44	17	31
/f/	65	15	85	85	85	55	100	100	70
/θ/	35	20	15	10	0	0	5	0	0
/ʃ/	85	5	85	100	100	90	95	0	100
/h/	No stimuli in this position								
/v/	65	5	40	85	75	80	65	0	15
/ð/	40	0	10	35	15	5	0	0	0
/z/	0	5	0	0	0	0	0	0	0
Liquids:	72	58	38	92	68	72	75	60	52
/r/	50	60	55	90	40	55	95	70	80
/l/	95	55	20	95	95	90	55	50	25
Semi-cons: /w/	No stimuli in this position								

6.0 PHONETIC OBSERVATIONS

In order to translate the numerical results into meaningful terms, the following arbitrary conventions were adopted: Correct identifications of 80 % or over are assumed to be "good"--this allows a 20 % margin for errors not caused by linguistic, perceptual or technical factors. The range extending from 40 to 79 % correct identifications is designated as "marginal", and the range of zero to 39 % , "poor". All percentages were reduced to the nearest whole number.

6.1 AMERICAN LISTENERS / FRENCH STIMULI

Stops in initial position, paired with all three vowels, were marginally perceived when white noise was introduced. Perception was also marginal with the vowels /i/ and /a/ when a babbling voice background was present, and with the vowel /a/ under clear recording conditions. Voiceless stops in initial position were less frequently identified than the voiced stops, with /p/ poorly perceived against noise with all three vowels. In addition, /p/ was poorly preceived with /i/ and /a/ plus babbling. The perception of /pa/ and /pu/ was marginal also, even in clear recording conditions, as was /pu/ with babbling. /ta/ was poorly perceived in all three recording conditions. /ki/ was marginally perceived when white noise or babbling was present, and /ka/ was poorly identified with noise but marginally perceived with babbling. As for voiced stops, /da/ was marginally perceived when noise was present, and /gi/ and /ga/ were marginal with noise, as were /gi/ and /gu/ with babbling. Finally, /gu/ was poorly perceived when white noise was introduced.

Stops in medial position were marginal only with the vowel /a/ plus noise. /upu/ was marginal with babbling, as were /aka/ and /uku/ with noise. /idi/ was also marginally perceived when noise was present. Finally, /iki/ was poor-

ly perceived with both noise and babbling.

Stops in final position presented the greatest difficulties of all. They were marginally perceived with all vowels plus babbling. With the vowels /i/ and /ɛ/, they were marginally perceived against noise, but poorly perceived when paired with the vowel /u/. /up/, /ut/, /ik/ and /ak/ were marginally perceived in background-free contexts, as well. Clear recordings of /it/, /ib/, /ig/, /ak/, /ab/, /uk/, /ub/ and /ug/ were marginally perceived against noise, as were /it/, /id/, /ig/, /ap/, /ut/, /uk/, /ub/ and /ud/ against babbling. /p/ was poorly perceived when paired with /i/ or /u/ plus noise or babbling, as were /ik/ and /ud/. Finally, /ut/, /id/ and /ud/ were poorly perceived against noise.

The nasal, /ŋ/, in medial and final positions was marginally perceived against noise when paired with /i/. /uŋ/ was marginally perceived against babbling, and /uŋu/ was poorly identified against noise.

Affricates in initial position were poorly identified when paired with the vowels /i/ and /u/ against noise. /dʒ/ presented the greatest difficulties, as it was marginal in all conditions when paired with /i/, marginal in clear and babbling conditions with /u/ and poor with /u/ and noise.

In medial position, affricates were marginally perceived only when /i/ and noise occurred simultaneously. Once again, /dʒ/ presented the greatest difficulty as /idʒi/ was marginal in all 3 conditions, and /udʒu/ was marginal with babbling.

Finally, affricates in final position were marginal under clear conditions with the vowels /a/ and /u/, with /a/ plus babbling and with /u/ plus noise.

However, in this position there were difficulties with both /ʧ/ and /ʤ/. /ʧ/ was marginal in clear and babbling conditions, as was /uʧ/ plus noise. /ʤ/ was marginal in all conditions except with /a/ plus noise or babbling.

Fricatives were marginally perceived in all positions with all 3 vowels under all 3 conditions. Specifically, /θ/ and /ð/ were poorly perceived in all positions with all 3 vowels in all conditions.

In initial position, /fa/ was marginal with noise, as were /ha/, /vi/ and /vu/. /ha/ and /va/ were also marginal under clear conditions, as was /hu/ plus babbling.

In medial position, /ifi/, /afa/, /ihi/, /ava/ and /uvu/ were marginal against noise. /ihi/ and /ava/ were also marginal against babbling. /uhu/ was poorly perceived with both noise and babbling.

In final position, /if/, /af/ and /uʃ/ were marginal against noise as was /af/ against babbling. /v/ was marginal with all vowels in all conditions, with the exception of /uv/. Under clear conditions, /uv/ was highly intelligible.

Liquids in initial position were marginal with /a/ in all conditions and with /u/ in clear conditions or against noise. /lu/ was marginally perceived against noise. /r/ was marginal everywhere except /ra/, which was poor under clear and noise conditions.

In medial position, liquids were marginal under all conditions with /a/ and /u/. /ulu/ was poorly perceived against noise, as was /ara/ in all conditions. /uru/ was marginal in all conditions.

Liquids in final position presented the greatest difficulty, as they were mar-

ginally perceived in all conditions with all vowels, except with /a/ plus babbling, which was poor. /il/ was marginal with noise or babbling, as was /al/ with babbling. /ir/ was marginal even under clear recording conditions, but /ar/ and /ur/ were poorly perceived in all conditions.

The semi-consonant, /w/, presented difficulty only when paired with /u/ in initial position plus noise or babbling and in medial position with /u/ under all conditions.

6.2 AMERICAN LISTENERS / GERMAN STIMULI

In initial position, stops were marginally perceived with the vowels /i/ and /u/ when white noise or babbling voice background were added. Specifically, /p/ was poorly perceived with /i/ plus noise, and marginally perceived with /a/ and /u/ against noise, and marginally perceived with /i/ and babbling. /k/ was marginally identified with /a/ plus babbling, and poorly identified with /u/ and noise. /b/ was marginally perceived with /i/ plus babbling, with /a/ plus noise or babbling, and with /u/ under clear recording conditions; and was poorly perceived with /i/ against noise and with /u/ in white noise or babbling. /d/ was marginally identified against babbling and poorly identified against noise with the vowel /i/. Finally, /g/ was marginally perceived with /i/ plus babbling, and poorly perceived with /u/ plus noise. /t/ was clearly perceived across all conditions with all vowels.

In medial position, stops were marginally perceived with all vowels when noise was added, and with /u/ plus babbling. Specifically, /p/, /d/, and /g/ were marginally perceived with the vowel /i/ against noise. /p/ was poorly perceived with /u/ against noise. /k/ and /b/ were marginally identified with /u/ plus noise or babbling. /b/ was poorly perceived in all conditions with /a/. /b/, /d/, and /g/ were marginally identified with /i/ plus babbling.

/d/ was marginally perceived with /a/ and /u/ against noise. Finally, /g/ was marginally perceived with /u/ across all conditions of testing. /t/ was again clearly identified in all conditions with all vowels.

Stops in final position were poorly recognized with /u/ and white noise, and marginally perceived in all other conditions with all vowels. /p/ and /k/ were marginally identified with /u/, /t/ with /a/, and /g/ with /i/ when noise or babbling were added. /g/ was also marginally identified with /a/ against noise and poorly identified with /u/ across all conditions. /b/ was extremely poorly identified in all conditions with all vowels, since it was usually perceived as /p/. Finally, /d/ was poorly perceived in all conditions with all vowels except with /u/ under clear recording conditions, where it was marginally perceived.

Affricates in initial position were marginally perceived with the vowel /a/ plus white noise or babbling, and with /u/ under clear recording conditions or noise. Also, affricates were poorly perceived with /u/ against babbling. Specifically, /ʧ/ was marginally identified against noise, and /ʤ/ against babbling with the vowel /a/. /ʧ/ was also marginally identified with /u/ plus noise or babbling. /ʤ/ was poorly perceived with /u/ in all conditions. /ʤ/ was often perceived as /ʧ/.

In medial position, affricates were marginally recognized with the vowel /i/ under all conditions, with /a/ against white noise, and with /u/ against babbling. Specifically, /ʧ/ was marginally perceived with /a/ against noise. /ʤ/ was marginally perceived with /u/ under clear recording conditions or babbling, and was poorly perceived with /i/ across all conditions. Again, /ʤ/ was often perceived as /ʧ/.

In final position, affricates were marginally perceived with /u/ across all conditions. Specifically, /ʧ/ and /ʤ/ were both marginally perceived with /u/ under clear recording conditions or noise. /ʤ/ was also marginally identified with /i/ against noise, and with /a/ against babbling; and was poorly identified with /u/ against babbling.

Fricatives in initial position were marginally recognized with all vowels across all conditions. Specifically /f/ was marginally perceived with /i/ against white noise. /θ/ was marginally perceived with /a/ against noise, and was poorly perceived with the vowels in all other conditions. /θ/ was usually perceived as /s/ or /z/. Against white noise or babbling, /h/ was marginally recognized with /i/ and /u/, and poorly recognized with /a/. Both /v/ and /ð/ were poorly perceived with all vowels across all conditions. /v/ was usually perceived as /f/,and /ð/ was usually perceived as /z/. Finally, /z/ and /ʃ/ were clearly perceived in all cases.

In medial position, fricatives were marginally perceived with all vowels across all conditions. Against noise, /f/ was marginally identified with /u/. /v/ was marginally identified with /a/ against babbling. /θ/ and /ð/ were poorly perceived with all vowels across all conditions since they were never perceived correctly. /θ/ was usually perceived as /s/, and /ð/ as /z/. Finally, /ʃ/, /h/, and /z/ were clearly perceived in all cases.

Fricatives in final position were also marginally perceived with all vowels across all conditions. Specifically, /θ/, /v/, and /ð/ were poorly perceived with all vowels across all conditions, with /θ/ and /ð/ never being correctly perceived. /θ/ was usually perceived as /s/ or /z/, and /ð/ was again perceived as /z/. Against babbling, /z/ was marginally perceived with /i/. Finally, /f/ and /ʃ/ were clearly perceived across all conditions with

all vowels.

In initial position, liquids were marginally perceived with the vowel /a/ across all conditions, and with /i/ and /u/ under clear recording conditions. Liquids were poorly perceived with /i/ and /u/ against noise or babbling. Specifically, /l/ was marginally identified with /i/ against noise or babbling, and marginally identified with /u/ against noise. /l/ was also poorly identified with /u/ plus babbling. /r/ was poorly perceived with all vowels in all conditions, with only one exception: /r/ was marginally perceived with /i/ under clear recording conditions.

Liquids in medial position were marginally identified with the vowels /a/ and /u/ under all conditions, and with /i/ against noise or babbling. With the vowel /i/, /l/ was marginally perceived against noise or babbling, and /r/ was marginally perceived against noise. /r/ was also marginally identified with /a/ plus noise, with /w/ under all conditions, and was poorly perceived with /a/ under clear recording conditions or babbling.

In final position, liquids were marginally perceived with /i/ and /u/ under all conditions, and with /a/ under clear recording or babbling. Liquids were poorly perceived with /a/ against noise. Specifically, /l/ was marginally perceived with /u/ against noise or babbling, with /a/ against noise, and with /u/ under clear recording conditions or babbling. /l/ was poorly perceived with /u/ against noise. With /u/, /r/ was marginally perceived against noise. /r/ was poorly perceived with /i/ under clear recording conditions or babbling, and with /a/ under all conditions.

In initial and medial positions, the semi-vowel /w/ was poorly perceived with all vowels across all conditions. /w/ was usually perceived as /v/.

In medial position, the nasal /ŋ/ was marginally perceived with the vowel /a/ against white noise. /ŋ/ in final position was marginally identified with /i/ against noise or babbling, and with /u/ under clear recording conditions or noise.

6.2 AMERICAN SUBJECTS / MEXICAN STIMULI

The plosives, /p/, /t/, /k/, /b/, /d/, and /g/, in initial position were identified with greater regularity than in final position, but not as well as in medial position. Degree of intelligibility divided itself into the two classes of plosives: voiced and unvoiced. All of the unvoiced plosives, /p/, /t/, and /k/, comprising twenty-seven stimuli, were poorly perceived with all vowels in all conditions with the exception of /ti/ and /ka/ which were marginally perceived. Of the voiced plosives, four of the twenty-seven stimuli were poorly perceived, three of them with the vowel /i/ and one with /u/. Of those with /i/, two, /gi/ in the clear recording, and /di/ with babbling, were not perceived at all; the other stimuli, /di/ with noise, was perceived correctly 15% of the time. All of the voiced plosives were marginally perceived with the vowel /a/ and babbling. /b/ was highly perceived most of the time excepting /bi/ with white noise and /ba/ with babbling, which were marginally perceived.

In medial position, the situation was reversed, the unvoiced plosives being much more highly intelligible than their voiced counterparts. This was to be expected due to the fact that in Spanish voiced plosives in intervocalic position become fricatives, apparently making it difficult for American subjects to identify them. Of the voiced plosives, /b/ was poorly perceived with all vowels and all conditions, and essentially not perceived at all with the

vowel /i/; /d/ was almost as poorly perceived throughout, excepting for /udu/ with noise or with babbling, which was marginally perceived; /g/ was poorly perceived with the vowels /i/ and /u/ with noise and with babbling; in the clear recording, it was marginally perceived. With the vowel /a/, /g/ was highly understood.

In final position, again the voiced plosives were less understood for the same reason given above, but in this position, some of the stimuli with unvoiced plosives were also poorly understood in contrast to the medial position. None of the voiced plosives were perceived with the vowel /u/ and babbling; the unvoiced plosives with the same vowel and condition were poorly perceived with /uk/ not perceived at all. Of the voiced plosives, /b/ and /d/ were poorly perceived throughout with the exception of /ib/ with noise (marginally perceived) and /id/ with noise (highly perceived); /g/ was poorly perceived with vowels /a/ and /u/ with noise and with babbling; the clear recording was marginally perceived. With the vowel /i/, /g/ was poorly perceived with babbling, otherwise, it was well perceived. Of the unvoiced plosives, /k/ was poorly understood with all vowels and conditions except /ak/, which was marginally perceived; /p/ and /t/ were poorly perceived with the vowels /i/ and /u/: /ip/ and /up/ with noise or with babbling, and /it/ with noise and /ut/ with babbling; otherwise /p/ and /t/ were marginally perceived except for /at/ with noise and /ut/ with the clear recording which were highly intelligible.

The nasal /ŋ/ in medial position was poorly understood with the vowels /a/ and /u/ except for /aŋa/ in the clear recording which was marginal. With the vowel /i/, it was poorly understood with noise, and marginally with the clear recording or babbling.

In final position, this nasal was poorly perceived throughout, experiencing its worst perception with the vowel /a/, with which it was essentially not perceived.

The affricates in initial position were misunderstood more than in the other positions. They were poorly understood with the vowel /u/ with noise or with babbling; /dʒu/ was not correctly perceived at all; in the clear recording, they were perfectly understood. With the vowel /a/, /dʒ/ was poorly perceived with noise and with babbling while /tʃ/ under the same conditions was well perceived. They both were well perceived in the clear recording. With the vow- /i/, /dʒ/ was poorly perceived with noise, otherwise, highly understood (As a matter of fact, /dʒ/, a non-existent phone in Spanish, and pronounced /ŷ/ on the tape, was perfectly understood by native Americans with all vowels in the clear recording condition); /tʃ/ was marginally understood in the clear recording condition, and well understood with noise and with babbling.

In medial position, only /dʒi/ with babbling was poorly understood; in the other two conditions (clear and noise) with the same vowel, /dʒ/ was marginally understood; /tʃ/ was almost perfectly perceived with this vowel in all three conditions. Conversely, /tʃ/ was marginally perceived with the vowel /u/ with the clear recording and with babbling (with noise it was highly intelligible), while /dʒ/ was highly perceived. Both affricates were well perceived with the vowel /a/ in all conditions.

In final position, only /dʒa/ was poorly perceived with noise; in all other cases with the three vowels and the three conditions, both affricates were well perceived.

The fricatives in initial position presented the greatest difficulty for American listeners; the medial position was almost identical in difficulty, and the final position presented the least difficulty although many of the stimuli were still poorly understood. With the vowel /i/, all the fricatives were poorly perceived with the exception of /fi/ and /hi/ under clear recording conditions. With the vowel /a/, again, most of the fricatives were poorly perceived, except /f/, which was marginally perceived (all conditions) as was /hi/ with a clear recording. With /u/, four of the fricatives, /ʃ/, /v/, /ð/, and /z/, were poorly perceived; /fu/ and /θu/ with a clear recording condition and /hu/ with noise or with babbling were marginally perceived; /hu/ with the clear recording was well perceived.

In the medial position, /θ/, /ʃ/, /ð/, and /z/ were for the most part poorly understood with all vowels and conditions. With the vowel /a/, /f/ and /h/ were marginally understood except for /fa/ with the clear recording which was perfectly perceived. With the vowel /i/, /f/ was fairly well understood while /h/ and /v/ were basically marginal. With the vowel /u/, /f/ and /h/ were well understood, while /v/ was marginally understood.

In final position, /θ/, /ð/, and /z/ were poorly perceived. With the vowels /i/ and /u/ all the fricatives were poorly perceived with noise, excepting /uf/ which was clearly perceived. /ʃ/ was well perceived throughout except for /if/ and /uf/ as indicated above.

The liquids /l/ and /r/ in initial position were generally perceived better than in the other two positions. With the vowel /i/, both were marginally perceived with noise and with babbling; with the clear recording, they were well

perceived. With the vowel /u/, /l/ was marginally perceived with noise and babbling; with the clear recording it was well perceived; /r/ was well perceived in all conditions. With the vowel /a/, both liquids were well perceived in all conditions.

In medial position, /l/ was not understood as well as /r/. With the vowel /i/, /l/ was poorly perceived in all conditions, while /r/ was perceived poorly only with noise; it was marginally perceived with the clear condition and with babbling. With /u/, again /l/ was poorly understood this time with the clear recording condition and with babbling; with noise, it was marginal; /r/ was marginally perceived with babbling, but well understood with the clear recording and with noise.

In final position, only /l/ was poorly understood: /il/ and /ul/ both with babbling. With /i/, /r/ was marginally perceived contrasting with /l/ and the vowel /a/ which was very well perceived.

The semi-vowel /w/ was marginally to poorly understood in both positions tested. In initial position, it was poorly perceived in all conditions. With the vowel /u/, it was poorly perceived with noise and with babbling; it was marginally perceived with the clear recording. With /a/, it was marginally perceived with the clear condition and with noise while well perceived with babbling.

In the medial position, /w/ was poorly perceived with /u/ (all conditions), and with the vowel /i/, it was poorly perceived with the clear recording condition and with babbling; it was marginally perceived with noise. With /a/, it was marginally perceived with the clear recording condition and with bab-

bling; with noise, it was perfectly perceived.

3.4 FRENCH SUBJECTS / AMERICAN STIMULI

Stops in medial position were better perceived than in initial position, but were poorly perceived in terminal position.

In initial position, stops were highly intelligible under clear recording conditions. For the other conditions the results were marginal. /pa/ was marginally perceived with white noise and babbling, and /pu/ was poorly perceived against babbling. With babbling, /t/ was marginally perceived with the vowels /i/ and /u/ and poorly perceived with /a/. With white noise, /k/ was marginally perceived with /i/ and poorly perceived with /a/. Against babbling, /k/ was poorly perceived with /i/ and /u/ and marginally perceived with /a/. /b/ was marginally perceived only with /a/ and with babbling. /d/ was marginally perceived with /i/ and white noise and with /i/ and /u/ plus babbling. /g/ was marginally perceived with /i/ and /u/ against noise and with /u/ against babbling.

In medial position, the results were quite good. /g/ was marginally perceived with /u/ against noise. Against babbling, /k/, /d/ and /g/ were marginally understood with /i/. With the vowel /u/, all stops but /t/ were marginally perceived.

In terminal position, results were poor in general. In the clear condition, /d/ and /g/ were marginally perceived with /i/, /b/ and /d/ with /a/, and /p/ with /u/. /g/ was highly intelligible with /a/ in the clear recording condition and with white noise.

The nasal stop /ŋ/ was poorly perceived with all vowels and recording condi-

tions, in medial position.

In terminal position, the results were mixed, but were poor with the vowel /u/ in all conditions.

Among the affricates in initial position, /tʃ/ was marginally perceived with /i/ in the clear recording condition, with /u/ against noise, but was poorly perceived with /u/ against babbling. /dʒ/ was marginally perceived with /i/ and babbling only.

The affricates were highly intelligible in medial position with each vowel and each condition.

In terminal position, /tʃ/ was well perceived in all conditions with all vowels. /dʒ/ was marginally perceived with /a/ and white noise, and with /u/ and babbling. /dʒ/ was poorly perceived with /a/ against babbling.

The results of the fricatives were slightly better in medial position than in initial position but generally poor in terminal position.

In initial position, /f/ was marginally perceived with /a/ in the clear recording condition, and with /i/ and /u/ against white noise and babbling. /θ/ was poorly perceived most of the time except with /u/ in the clear condition and with /a/ and /u/ against white noise. /ʃ/ was well perceived except with /i/ and babbling. /h/ was poorly perceived with /i/ against white noise and babbling, marginally perceived with /a/ against babbling and not correctly perceived at all with /u/ against babbling. /v/ was marginally perceived with /i/ in all conditions and poorly perceived with /a/ in all conditions. /ð/ was marginally perceived with all vowels in all conditions. /z/ had a fairly good intelligibility.

In medial position, /f/ and /ʃ/ were well perceived with each vowel and in condition. /ʊ/ was marginally perceived in all conditions with /i/ and poorly perceived with /a/. /h/ was marginally perceived with /u/ against white noise and with /i/ and /u/ against babbling. /v/ was poorly perceived with /i/ and /a/ against white noise. /ð/was marginally perceived except with /a/ in the clear condition and with /u/ against babbling which gave poor results. /z/was marginally perceived only with /a/ against white noise.

In terminal position, the results are clearer. /f/, /ʃ/ and /z/ were well perceived most of the time. /ʊ/ and /ɒ/ were poorly most of the time except with /i/ in the clear recording condition. /v/ was poorly perceived only with /i/ plus babbling.

Liquids were well perceived in initial and medial position but poorly perceived in terminal position.

In initial position, /l/ was marginally perceived with /a/ against babbling and /r/ with /u/ in the same condition.

In medial position, /l/ was marginally perceived with the vowel /a/ in all conditions and with /u/ against babbling. /r/ was highly intelligible in all condition and with all vowels.

In terminal position, /l/ was poorly perceived most of the time. /r/ was well perceived except with /a/ plus white noise and babbling.

The results of the semi-vowel were generally good. In initial position, /w/ was marginally perceived with /a/ and /u/ against babbling and poorly perceived with /u/ against white noise.

in medial position, /w/ was marginally perceived with /u/ against white noise and babbling.

6.5 GERMAN SUBJECTS / AMERICAN STIMULI

In initial position the stops were perceived marginally with babbling background and the vowel /i/, and in combination with the vowel /u/ with white noise and babbling. The consonant that was most poorly identified is /k/. In combination with the vowel /i/ and babbling, only 30 % of the listeners perceived a /k/. This was also true, when /k/ appeared with the vowel /u/ and white noise. When it occurred with /u/ and babbling, not more than 15 % of the listeners recognized the consonant as a /k/. Also poorly perceived in initial position were /p/ and /g/ in combination with the vowel /u/. Only 25 % of the subjects recognized the syllable /pu/ as such when it occurred with babbling. And the syllable /gu/, in combination with noise, was correctly perceived by only 30 % of the listeners.

In internal position, almost all the stops were highly perceived, except when they were paired with the vowels /i/ and /u/ and babbling. As in initial position, the consonant /k/ was also poorly perceived with babbling in internal position, but this time in combination with the vowel /a/ only. Also poorly recognized with babbling was /g/ in the syllables /gi/ and /gu/.

In terminal position all the stops were poorly perceived, except when they occurred with the vowel /a/ and no background noise at all. The most marginally perceived stop in terminal position was /d/. It was always marginally heard, when it appeared together with the vowel /i/. Furthermore it was marginally recognized in the syllable /du/, when there was no noise or babbling. The consonant /g/ was twice marginally identified in combination with the vowel /a/,

one time with noise, the other time with babbling in the background. Also marginally identified were /b/ and /k/ with the vowel /a/ and a clear background.

The nasal /ŋ/ was only used in internal and terminal position. In internal position it was poorly recognized with the vowels /i/ and /u/ whenever there was noise or babbling in the background. With the vowel /u/ the perception was even poorly when the background was clean. /ŋ/ was marginally identified in combination with /i/ and /a/, the former with no noise, the latter with babbling.

In terminal position /ŋ/ was mostly identified poorly. This was the case when it occurred with the vowels /i/ and /u/, with or without background noise. It was marginally perceived in the syllable /aŋ/, with and without noise.

In initial position the affricates were marginally identified with the vowel /i/ under clear conditions and with babbling, with the vowel /a/ and babbling, and with the vowel /u/ in all conditions. Only the affricate /tʒ/ was poorly perceived in the syllable /tʒu/ when babbling was added.

In internal position they were only once marginally perceived: when they occurred in combination with /u/ and babbling. This is true for /tʒ/ as well as for /dʒ/.

In terminal position all affricates were marginally recognized with babbling and the vowels /i/ and /u/. They were poorly percieved in combination with the vowel /a/ and babbling. Furthermore /dʒ/ was marginally identified with the vowel /a/, in clear conditions and with noise. It was poorly perceived with /a/, when babbling was added.

In initial psition, the fricatives as a whole were marginally perceived. The least frequently recognized consonant, though, was /θ/, followed by /ð/ which was only once identified marginally and that was in combination with /a/ and babbling. Most marginally recognized was /v/, which was also poorly identified with babbling with the syllable /va/. Also marginally perceived was /z/ with the vowel /a/, when it appeared under clear conditions or with babbling. /f/ was marginally recognized with the vowel /i/ and noise, with the vowel /a/ with noise or babbling, and with the vowel /u/ against noise. The fricative /h/ was also marginally recognized in the syllable /hu/ when noise or babbling was added, in the syllable /ha/ with babbling, and in the syllable /hi/ with noise.

In internal position, the fricatives on the average were marginally perceived. Here, the most poorly identified one was /ð/, then followed by /θ/, which was marginally recognized only with the vowel /i/ and no noise. The vowel /v/ was almost always marginally perceived. /f/ was marginally recognized in combination with the vowel /i/ in all conditions and with the vowel /a/ and noise. The perception of /h/ was generally high, except for when it appeared with the vowel /u/. Then it was poorly identified with noise, and marginally with babbling.

In terminal position, too, the fricatives as a whole were identified marginally, except for those that occurred with the vowels /i/ and /a/ against babbling. Here the perception was poorly. As in internal position, in terminal position /ð/ was again the most poorly recognized fricative, again followed by /θ/. And /θ/ was, as in internal position, again marginally recognized once, and also as in internal position - when it appeared with the vowel /i/ under clear conditions. The fricative /z/ was poorly recognized in combination with the vowel /a/ against babbling. The most highly identified fricative of all was /ʃ/. It was only marginally perceived once: in initial position with the

vowel /i/ and noise.

In initial and internal position the liquids, on the average, were well perceived. In initial position, though, /r/ was marginally identified with the vowel /i/ against noise or babbling, and /l/ with the vowel /a/ against babbling.

In internal position the perception of /l/ was marginally in combination with /a/ and noise or babbling.

In terminal position the average identification of the liquids was marginal, except when they occurred with the vowel /a/ and no noise, they were poorly identified, and with the vowel /a/ and no noise they were highly recognized. Furthermore /r/ was marginally perceived with the vowel /a/ against noise and babbling, and with the vowel /i/ against noise.

The semivowel /w/ was only recorded in initial and internal position. In initial position it was always marginally recognized with the vowel /u/. The perception was also marginal, when /w/ occurred in combination with the vowel /a/ against noise or babbling, and with the vowel /i/ with a clear background.

In internal position it was marginally identified with the vowel /u/ against babbling or under clear conditions, and poorly against noise. Its identification was also marginal with the vowel /i/, with babbling and without noise, and with the vowel /a/ and babbling.

6.6 MEXICAN SUBJECTS / AMERICAN STIMULI

The plosives, /p/, /t/, /k/, /b/, /d/, /g/, in initial position were understood much better than in final position, but not as well as in medial. Their perception was marginal with all three vowels, /a/, /i/, and /u/, under white noise

and babbling conditions. Subjects had the most difficulty in identifying these consonants with the vowel /u/: /ku/ and /gu/ were poorly perceived with white noise, and /pu/ and /ku/ were poorly perceived with babbling voices. With the vowel /a/, perception was also marginal under clear recording conditions, and /pa/ was the only stimulus with babbling understood poorly. With the vowel /i/, as with the vowel /u/, all the plosives were highly intelligible with limited bandwidth; /ki/ was poorly perceived with babbling.

The plosives were best understood in medial position. They were highly intelligible with all vowels in clear recording conditions with the exception of /ba/, which was marginally understood. There were only three stimuli poorly understood in this position: /igi/ and /aka/ with babbling, and /ugu/ with noise. The plosives were marginally perceived with vowels /i/ and /u/ and babbling, with the exception of /upu/ and /utu/ which were perceived well. /iki/, /ibi/, /igi/, /upu/ and /uku/ were perceived marginally as well with noise.

In final position, thirty-eight stimuli (70 %. of the plosives) were poorly perceived, clearly demonstrating the extreme difficulty a native speaker of Spanish has in perceiving stops in final position. All stimuli were poorly perceived with the vowels /i/ and /u/ in all conditions excepting /id/, /ig/, /up/, and /ub/ in the clear recording, and /id/ with noise, which were marginally perceived. With the vowel /a/, four of the plosives were poorly perceived with babbling, and two, /at/ and /ag/, were marginally perceived. With white noise, /ip/, /it/, and /ub/ were poorly perceived; the rest were marginal.

The affricates in initial position were marginally and poorly understood with all vowels with the exception of /dʒi/ and /tʃa/ which were highly intelligible under a clear recording condition. As with the plosives, the affricates were least understood with the vowel /u/, /tʃu/ being poorly perceived with white noise and babbling. (It was interesting to find that eventhough /dʒ/, a non-existent phoneme in Spanish, was marginally perceived with all vowels except as noted above, it was never perceived poorly as was the case for /tʃ/, a standard phoneme in Spanish).

In medial position, the vowel /u/ presented listeners with the greatest difficulty in perception: /tʃ/ was marginally perceived with all three conditions, and it was with this vowel that both affricates, /tʃ/ and /dʒ/, were marginally understood with the clear recording. An unexpected result was the high intelligibility of both affricates with the vowel /i/ with babbling.

In final position, it was /dʒ/ and not /tʃ/ which was poorly understood: with the vowel /u/ and conditions of noise and babbling; and with the vowel /a/ with babbling. As was expected for all positions but which only occurred in this one, /tʃ/ was highly intelligible with all vowels and all conditions. (Again it is interesting to note that in the usual environment of /tʃ/, initial and medial positions, this phoneme was marginally perceived for the most part, while in the final position, an invalid context for this phoneme in Spanish, our Spanish speaking listeners demonstrated little difficulty in identifying it).

The only nasal used in the test, /ɲ/, was recorded in two contextual positions. In medial position, it was poorly perceived with all vowels in all conditions.

In final position, it was poorly perceived with the vowel /u/ in all conditions, with the vowel /i/ with noise and babbling, and it was marginally perceived with the vowel /a/ with all conditions. The single time that it was highly perceived was in this position with the vowel /i/ in the clear recording condition. (It should be noted that /ŋ/ is not phonemic in Spanish, but that it does exist as a phone with a very low functional load. Consequently, it was perceived by Spanish listeners as /n/, a perceptually similar phoneme in Spanish).

Of all the phonemes tested in initial position, the fricatives, in general marginally and poorly perceived with all vowels, presented the greatest area of difficulty for Mexican and Chicano listeners. /θ/, a non-existent phoneme in Mexican Spanish, was barely perceived with all three vowels (all conditions), and not perceived at all with the vowel /i/ (all conditions). /ð/, an allophone of /d/ in Spanish in medial and final positions, was also very poorly perceived with the exception of /ða/ and /ði/ which were marginally perceived with the clear recording condition. /fi/ and /va/ were the only other fricatives poorly understood, both with babbling. /ʃ/ was marginally perceived with all vowels and all conditions, as was /v/, with the exception noted above with the vowel /a/, and with the vowel /u/ in the clear recording which was highly perceived. Of interest also was that /z/ was highly perceived with all vowels and all conditions, as were /f/ and /h/ with all vowels in the clear recording only.

In medial position, the results were practically identical to those in initial position. In this position, /f/ and /h/ could be understood much better in more conditions, but /θ/ and /ð/ remained practically the same. /z/ be-

came marginal with all three vowels in the babbling condition.

In final position, again perception of /θ/ and /ð/ remained about the same, and the perception of /v/ and /z/ was at its worst: /v/ was poorly perceived with the vowel /i/ with noise and babbling, and /z/ was poorly perceived for the first time with the vowels /a/ and /u/, both with babbling. The perception of /ʃ/ remained constantly marginal in all three positions.

The liquids, /l/ and /r/, in initial position were highly perceived with all vowels and all conditions with two exceptions: /ri/ with babbling, and /ru/ in the clear recording were both marginally perceived.

In medial position, again for the most part, both liquids were highly intelligible. This time it was /l/ which was not identified as much as the other liquid: /ala/ in the clear recording, and /ala/ and /ulu/ with babbling were marginally understood. /uru/ with noise was the only instance in this position which was marginally misunderstood.

In final position, the perception of the liquids reached its lowest point. /l/ was poorly perceived with the vowel /u/ in all conditions, and /r/ was poorly perceived with the vowels /a/ and /u/ with noise. /l/ was marginally perceived in all other cases, as was /r/, except with the clear recording, in which case it was highly perceived.

The single semi-vowel, /w/, used in the test was used in two positions. In initial position, this phoneme was poorly perceived only once, and this was with /u/ and white noise. In the other two conditions with /u/, it was marginally

perceived, as it was with /a/ and babbling. Otherwise, it was very well perceived.

In medial position, it was marginally understood with /u/, and highly perceived with /i/ and /a/.

7.0 GENERAL CONCLUSIONS OF STUDY

7.1 DEGREE OF SUCCESS OF STUDY

It is gratifying to note that all the team's scientific goals have been accomplished. Moreover, the study has been a valuable learning experience for all members in team research and experimental design. It must be kept in mind, however, that this should be considered a pilot study, one which will provide direction rather than conclusive recommendations. For example, a number of interesting cross language phonetic patterns have emerged which appear highly credible and must be tested in depth at a future date. Further, we have isolated a few areas of international voice communication difficulties, and shall present a few preliminary recommendations.

7.2 ANALYSIS OF WEAKNESSES AND LIMITATIONS

The weaknesses and limitations of the study were self-imposed due to time limitations. An in depth study on this subject would have to eliminate as many of the following as possible. More languages must be tested, to include the Oriental and Scandanavian languages if the subject in relation to international voice communications (air traffic control) is to be addressed adequately. Secondly, only one native speaker was used on the team both to interpret the answers of his countrypersons and provide the dialect on the test for interpretation by other nationalities. It is unrealistic to assume that one native speaker can ad-

equately represent all such native speakers. This self imposed limitation due to time and budget could be alleviated by placing more than one native speaker on the team, and utilizing more than one native speaker on the test. Third, the test sessions were too long. Subjects had to listen for one hour and thirty minutes to nonsense syllables, with annoying background in conditions number two and number three. The sessions were necessarily this long due to the time restrictions of this ten week study. In the future, testing sessions should be stretched out over a longer period of time and restricted to no longer than one hour. Fourth, the background interference in condition number two and number three were set at arbitrary levels. For the full impact of the effect these conditions have on cross-language communications a number of thresholds should be tested. Finally, probably the largest problem involves the interpretation of subjects' responses. It is extremely difficult to avoid misunderstanding when the communicated matter is expressed first verbally, then interpreted in writing. Proper pilot tests must precede testing in future study, with subjects' responses verbally explained so patterns of written interpretation could be developed for each language.

7.3 RESULTS

The numerical data presented in the preceding section is rich in information pertaining to the cross-language intelligibility of phonemes as this is affected by the various contextual and technical factors studied. Vowel context, for example, differentially affects the perception of certain consonants in certain positions in the utterance. White noise is more likely to affect the perception of fricatives than of other classes of consonants. These and other effects could not be analyzed in detail within the scope of the present study but the participants who may write up the results for publication will be able to

further exploit the data.

7.3.1 OVERALL AVERAGES BY PHONEME CLASS IN PERCENTAGES

Language of listeners / Stimuli accent		Amer. French	Amer. Germ.	Amer. Mexic.	French Amer.	Germ. Amer.	Mexican Amer.
STOPS	initial	74	79	92	81	80	72
	medial	90	80	56	89	88	81
	terminal	65	52	30	26	20	27
NASAL	initial	no stimuli in this position					
	medial	82	92	36	15	44	12
	terminal	86	84	10	44	37	31
AFFRICATES	initial	84	70	59	84	75	62
	medial	87	73	82	98	88	78
	terminal	77	80	87	84	69	69
FRICATIVES	initial	59	53	16	66	60	56
	medial	60	68	33	73	65	58
	terminal	53	48	37	62	49	43
LIQUIDS	initial	74	46	80	88	90	92
	medial	72	72	60	88	92	87
	terminal	57	53	65	44	60	49
GLIDE	initial	85	1	43	77	66	77
	medial	81	0	38	89	63	84
	terminal	no stimuli in this position					

7.3.2 OVERALL AVERAGES BY COMMUNICATIONS CONDITION

Language of listeners / Stimuli accent		Amer. French	Amer. Germ.	Amer. Mexic.	French Amer.	Germ. Amer.	Mex. Amer.
CONDITION No. 1 (Clear restricted bandwith)	initial	77	82	49	87	83	79
	medial	82	76	55	87	84	77
	terminal	72	61	51	58	54	53
CONDITION No. 2 (White Noise)	initial	60	52	32	74	69	64
	medial	69	66	47	79	74	68
	terminal	58	51	38	48	39	38
CONDITION No. 3 (Babbling)	initial	71	57	33	64	63	57
	medial	79	69	45	75	71	64
	terminal	59	55	37	40	29	30

7.3.3 PERCENT PERCEPTION PER POSITION

Language of listeners / Stimuli accent	Amer. French	Amer. Germ.	Amer. Mex.	French Amer.	Germ. Amer.	Mex. Amer.
Initial position	69	63	38	75	74	67
Medial position	77	70	49	80	73	70
Terminal position	63	53	42	49	47	40

7.3.4 SUMMARY OF RESULTS

Charts 7.3.1, 7.3.2, and 7.3.3 summarize the overall results of the project in terms of each language accent used and each group of listeners tested. They also present the results in terms of the class of phonemes used and position in stimulus, the condition used and position in stimulus, or solely in terms of the position averaging the effect of phoneme classes and communications conditions.

Chart 7.3.1 shows that in terms of the classes of phonemes, the stops in final position were by far the most difficult phonemes to identify for all listeners, especially for those listeners whose native language was other than English. The next troublesome group of phonemes were the nasal, and the fricatives in initial and terminal positions which were correctly identified about one half of the time. The rest of the classes of phonemes were marginally perceived except for the stops in initial and medial positions which were identified correctly on an average of at least 80 % of the time.

Chart 7.3.2 shows that in terms of conditions, the stimuli most difficult to perceive were in conditions 2 (noise) and 3 (babbling) in terminal position where stimuli were incorrectly identified more than half of the time. The rest of the time, the average response was marginal, with a number of listeners responding well with some language accents.

Chart 7.3.3 gives an overall index to the success that listeners had in identifying correctly the consonants presented to them in the three positions tested. As expected, consonants in intervocalic position were more readily identified than in the other two positions due to the greater information communi-

cated to listeners in terms of formants preceding and succeeding the production of the consonants in question. The average correct responses for all languages combined for all stimuli given was 70 % for intervocalic position; 64 % for initial position; and 49 % for final position. That is to say, that of all the consonants heard in intervocalic position (all vowels and all conditions), 30 % were not identified correctly; in initial position, over a third, or 36 % were not understood; and in final position, more than half were misunderstood. Taking an average of all three positions, the one figure that summarizes all tests given for all accents, is 61 % . This means that 39 % of all the stimuli given was not intelligible to sixty participants that listened to French, German, Mexican, and American accents of English. This is quite significant in helping us us understand, at least in part, why crosslanguage communication problems exist. It is evident that if 39 % of the information carrying units of speech are missing, faulty communication will necessarily occur.

Future plans include an analysis of difficulties particular to each language.

8.0 RECOMMENDATIONS

8.1 PHONETIC RECOMMENDATIONS FOR IMPROVEMENT OF INTERNATIONAL VOICE COMMUNICATIONS

For the improvement of crosslanguage air control jargon, the following recommendations are made.

Americans who find themselves in crosslanguage situations should be made aware of the great difficulty that French, German, and Mexican listeners of American English have with the following consonants: (1) stops in final position, (2)

the nasal /ŋ/ in medial position and (3) the fricatives /θ/ and /ð/ in all positions. A special effort must be made to pronounce these phonemes as carefully as possible even under the best communications conditions. Limited bandwidth, white noise, and babbling voices progressively worsen their comprehension. In addition, Germans exhibit difficulties in perceiving /ŋ/ in final position, and speakers of Mexican Spanish, who seem to have the most difficulty of the three language groups, do not identify the following well: (1) /ŋ/ in final position, (2) the affricates in initial and final position, (3) the fricatives /ʃ/ and /v/ in all positions and /z/ in final position and (4) liquids in final position.

On the other side of the coin, Americans should realize that they have serious difficulties in understanding English when it is spoken with a foreign accent, in this case, particularly with a French, German, or Mexican accent. Foreign language speakers of the aforementioned languages and American listeners of such accents should make special efforts to communicate the following phonemes: (1) the fricatives /θ/ and /ð/ in all positions and (2) the liquid /r/ in final position. In addition, Americans demonstrate significant difficulty in comprehending the following English phonemes with a German accent: (1) the stops /b/ in all positions and /d/ in final position, (2) the affricate /dʒ/ in medial and final positions, (3) the fricative /v/ in initial and final positions, (4) the liquid /r/ in initial and medial positions, and (5) the glide /w/ in initial and medial positions. Likewise, Americans have serious difficulty in identifying English phonemes with a Mexican accent: (1) the nasal /ŋ/ in medial and final positions , (2) the affricate /dʒ/ in initial position, (3) the fricatives /z/ in all positions, /h/ in initial and medial positions,

and /v/ in initial and final positions, (4) the liquids in medial position and (5) the glide /w/ in initial and medial positions.

Finally, it is recommended that persons who find themselves in international communications situations be indoctrinated in regard to the difficulties that arise in crosslanguage communication.

8.2 SCIENTIFIC RECOMMENDATIONS FOR CONTINUATION STUDIES

The Phonetics Research Facility of the University of California will presently make a formal application to NSF for a long-range continuation study of crosslanguage intelligibility. On the purely phonetic level, tests involving a number of speakers and improved testing conditions should be carried to verify the validity of the results of the present study. Then, parallel studies with other languages that are commonly used in situations such as international air-traffic control (Japanese, Scandanavian languages, other varieties of English, etc.) should be pursued. Vowel studies should be also undertaken before proceeding to the study of phonemes in meaningful contexts. Finally, pronunciation, and identification tests should be developed to screen air traffic control personnel and pilots who are to be assigned to international service, and a final revision of the vocabulary and syntax of standard expressions used in such situations.